Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

A PERPETUAL SUBMARINE WAR

By R. E. COKER

ASSISTANT, IN CHARGE SCIENTIFIC INQUIRY, U. S. BUREAU OF FISHERIES,
WASHINGTON, D. C.

NATIONS of men have battled with each other until they have become weary of war. Now they declare war against war. The recent world struggle, with all its consequences to every one concerned, was enough to reveal the folly of internecine strife. Besides, is it evidence of our boasted wisdom for groups of men to contend in mortal combat with one another while engaged against a common enemy? For all men are allies in a warfare more enduring than the disastrous conflict recently precipitated by the Central States of Europe, more wide-spread and pervasive in its actions, and at least equally critical in its bearing on the survival of the human race.

Our opponents in this war are small of stature, but in numbers they are legion. Conspicuous among these unrelenting adversaries are the tribes of insects. They, as well as others, wage war unceasingly upon us: they besiege our crops, they attack our buildings and our clothes, they destroy our animals, and they even attack our bodies with their poison darts, planting in us the germs of such diseases as yellow fever, typhoid, typhus and bubonic plague. It is like the war that Whitman sings of—"a longer and greater one than any, waged * * * with varying fortune, with flight, advance and retreat, victory deferred and wavering, and yet, methinks, certain, or as good as certain in the end." But—

Assuming that the worst came to the worst, that the insects had acquired mastery both on land and in the air—still we might retreat to the waters hoping to build submerged and protected homes. Should we find safety there? It is true insects are almost nonexistent in the sea, but they may have submarine allies. At any rate, we find there other dangerous enemies. Such are the boring animals of various groups which attack submerged structures of wood and even those of stone.

The principal naval powers opposing us are the shipworms, which, of course, are not worms at all, but rather are mollusks and not distantly related to the luscious oyster. It seems remarkable indeed that an animal of such ingratiating qualities and gentle habits as the oyster should have a near relative of even milder appearance which eternally engages in destruction of the property of man. New piling placed at great expense may be destroyed within a period of comparatively few months. Large and expensive buildings may be brought to collapse. Vessels of wood may be so weakened by the ravages of shipworms as to fall an easy prey to storms. Of course, the harm done by shipworms is often anticipated and such measures taken that the ships, buildings and wharves do not collapse, but these preventive measures are effected only at an annual expense which in the aggregate is enormous. The damage accomplished by shipworms each year can hardly be estimated, but when we are told by a reliable engineer that in the northern area of San Francisco harbor alone, the damage by marine borers made evident within a period of two years was estimated by competent engineers to be in excess of 15 million dollars, the imagination can frame some picture of the total losses in all parts of the world—to say nothing of the costs of defense in harbors and at sea.

What is this powerful submarine enemy called by so impotent a name as ''shipworm?'' If we can imagine an oyster having a very small shell, about the size of one's little finger nail, but with the body projecting from the rear end of the shell for a distance equal to the length of the finger or even of the whole arm, we have a very rough picture of the shipworm. The portion of the body protruding from the shell, practically the entire animal indeed, is surrounded by an extension of the soft mantle which lines the shell. Thus the animal is in the shape of a long tube, having the shell at one end and at the other two small tubular openings called siphons. No matter how far the shipworm may burrow into a plank or a log, the little siphons remain always at the outside pinhole opening through which the animal began its travels and destructive action in the wood. It is through these tubes that the Teredo breathes and derives the greater part of its food. Through one tube a stream of water steadily flows in, while through the other it flows out. In course of its passage through the animal the water bathes the small blood vessels, bringing in fresh supplies of oxygen and taking away the waste gases; it is also thoroughly filtered, yielding up to the animal the minute microscopic organisms and detritus required for food.

It is not strange that this mollusk lives so largely outside of its shell inasmuch as its life in burrows in the wood diminishes the need for a protective shell. Such of the shell as it retains about the forward end of the body is modified to form a grinding organ which is much more effective in its operations than one would suspect from a cursory examination. The shell is marked with ridges that in reality are composed of fine sharp teeth like those of the surface of a rasp. The two halves of the shell are not fitted together like those of a clam, where there is a hinge with an elastic ligament that keeps the shell valves apart except when they are drawn together by two strong muscles that pull together, one being near each end of the shell. In the shipworm the valves of the shell are pivoted above and below and while there are two muscles, as in the clam, it seems that, instead of pulling together, they contract alternately. The alternate action of the muscles therefore throws first the front edges of the shells together and then the rear edges. It is this rocking movement of the two parts of the shell which causes the rasp-like shell to grind away the wood ahead.

These little destructive carpenters are not known to be governed by any union rules but they grind away industriously and at least make a living at the job. For them indeed it is a living wage or death. If one puts an ear upon the surface of a piece of wood in which they are working, the rhythmic rasping sounds heard may give the impression that some creatures within are sleeping soundly. The impression will be erroneous; the sounds indicate merely that shipworms are doing a day's work for a day's wage.

Much of the fine sawdust produced by the rasping of the wood is taken into the stomach along with the living organisms from the water and it is yet a disputed question to what extent shipworms actually feed upon the wood which they continually grind up. To a large extent surely they feed upon organic matter, living or dead, which is carried in the sea water; this they strain out, as previously indicated, while the stream of water passes through their gill plates.

So far we have spoken of shipworms as if they were of one race or tribe. As a matter of fact there are several kinds of boring mollusks called shipworms besides boring animals of other groups. The principal boring mollusks belong to one family which scientists have maliciously named Teridinidæ. There are some boring mollusks which do not belong in the typical shipworm family. Among these is one called Pholas which bores in rocks such as limestone and sandstone, and occasionally wood, but never in hard or compact rocks. Another, euphoniously named Martesia, is found in timbers of wooden ships in West Indian waters. Xylophaga, which is not, as might be thought, a musical instrument, really accomplishes serious damage to marine structures and to the covering of submarine telegraph cables.

Giants among shipworms are the plumed pile-worms[1] which may be three feet in length and have a head diameter of nearly one inch or approximately the thickness of the human thumb. They are said to burrow at the rate of 1/8 inch a day; thus it can be seen that a great deal of damage can be accomplished by a few individuals in course of a few weeks. The increasing effectiveness of the attack may be appreciated when it is considered that they begin breeding at the age of 30 days and that a single healthy mother may cast millions of eggs into the sea water.

But the real king of the shipworms is the pet of our South Atlantic Coast, sometimes known as *Teredo dilatata*. A female which attains a length of 4 feet and a head diameter of 1 inch has the right to her "big head" for she lays one hundred million eggs at a sitting—enough to fill 4 or 5 thimbles. This apparent enormous waste in egg production is rendered necessary because great quantities of eggs or larvæ may be destroyed in the first few hours of life by physical conditions existing in the water or may be consumed as food by innumerable small floating animals.

The "shipworm" of the dykes of Holland[2] is less properly so called because it is not so often found in the timbers of ships as are other species. Its burrows are smaller and more symmetrical and regular than those of the giant pile-worm. It lives and dies within a year. The eggs are said to be held within the body of the maternal parent while they develop into free-swimming larvæ that subsequently escape into the sea. They are believed to remain in this free state about a month, during which they develop a "foot" and a pair of shells, before they settle down on wood and transform into the boring adult form. The number of eggs is estimated at a little less than two million. The free-swimming habit of the larvæ of this shipworm, and of the eggs and larvæ of those previously mentioned, is most significant because it enables the juvenile shipworms to travel long distances with the currents of the sea and thus to invade new territories.

The burrow of a shipworm enters the wood at right angles to the surface as a small pin hole, but soon turns and traverses it obliquely or parallel to the surface and usually downwards. The shipworm never bores completely through the wood but, guided by some instinct, the nature of which we can not define, it turns away just before breaking through the inner face of the wood. If, however, shipworms do not make a perforation completely through the bottom of a vessel they may so fill it with their burrows as to leave little more than an empty shell that is easily broken through by any blow or direct pressure.

Not all marine borers are shipworms. Any boy who has turned over a log of wood in the yard or in the forest may have observed the small "pillbugs" which live beneath the wood. These are crustacea belonging to the same large group of animals to which pertain the crabs, shrimps and lobsters. If a pillbug is left undisturbed for

---

[1] There are distinct species of this genus on our two main coasts, *Xylotra setacea* of the Pacific and *Xylotra gouldi* of the Atlantic.

[2] *Teredo navalis*.

a few moments it will be observed to unroll itself to assume a flattened form and crawl away. It might interest this boy to know that the pillbug has a relative in the sea called gribble (scientists call it *Limnoria lignorum*) which creeps into small crevices of wharf piles, even those which have been treated with creosote for protection, and, by gnawing away the wood, creates burrows which, when made in large numbers, will soon reduce the creosoted pile to an hour-glass shaped peg. The young have no free-swimming stage but, as soon as they leave the mother, begin to "dig in" for themselves. Hence they form family communities, and new colonies no doubt arise by the drifting of crumbled portions of pile to places where new homesteads may be established. A single square inch of wood has been found to contain nearly 400 individuals, adult and young. Another pillbug borer (Sphaeroma) digs into mud, wood, or even rock itself, but it seems to dig for shelter, not for food. Some of these are known to destroy piling in fresh-water.

Again, there is the feathered crustacean borer, called *Chelura tenebrans,* which works along with the pillbug borers and is known as a destroyer of wood both in Europe and North America. It is related to the familiar sand-hoppers or beach-fleas, though it has some external resemblance to the pillbug borers.

Our tale might be interminable if we proceeded to tell of the boring worms and the little sponges that make the familiar holes in the shells of oysters as well as in rock structures composed of limestone and that are of more economic importance than might at first appear. There are barnacles, too, that bore into limestone and coral.

Perhaps most interesting of all to the collector are the several kinds of boring clams which are often found encased in calcareous rocks. It is an exhilarating surprise to break with a hammer what appears to be a solid rock and in smooth oval burrows find completely formed clams entombed, as it were, within the rock but in healthy living condition. The chambers in which they live will be found to be connected with the outside only by small pores through which, with the usual currents of water, the clams derive their sustenance. Some of these cavities are undoubtedly excavated by the abrasive action of the rotating or rocking shell, but others are said to be found in rocks so hard that the excavation may not be supposed to have been effected solely by the mechanical action of the fragile shell. If an acid is employed in dissolving the rock it seems remarkable that the calcareous shell of the animal is not itself dissolved, and perhaps it would be except for the protective horny covering of the shell.

It is not to be assumed that the submarine war is altogether one-sided and that man has no means of defense against the destructive action of the marine borers. It has been held that, in some cases, at least, leaving the bark on wood piling affords some protection against borers but certainly this is a very poor defense, both because the bark itself may be attacked by borers, though they like it less than the wood, and because the bark is likely to be knocked off or cracked. It requires but a very small opening for the borers to get the first foothold after which their destructive action rapidly extends. Metal sheeting for piling is sometimes employed but a metal such as copper, which will withstand for a considerable period the corrosive action of salt water, is costly, tempting to thieves and liable to injury. Paints and treated burlap are also used but these are liable to damage from the contact of boats or drift, to the formation of cracks, and especially to injury in storms. Nevertheless there are coatings which have been found to give piling a life of 5 to 8 years. Concrete casings have been employed but great care is needed in their application and such casings are likewise subject to injury from the battering of boats against the piles.

An ingenious person once suggested the use of jointed collars of loose floats put in series around the piling with the idea that the continual battering of the floats from wave action would destroy the larvæ of the borers before they could effect an entrance into the wood. It requires, however, such a little break in the surface to harbor the minute larvæ of the borers that the plan does not seem to have been as effective in practice as it appeared to be in theory. Electrolysis and dynamite explosions have been employed for the destruction of the larvæ but the necessity of frequent repetition of the processes and perhaps other deficiences in their operation have prevented their demonstrating such results as could have secured their general adoption. For wood piling nothing more effective has yet been developed than impregnation with creosote oils which, while hot, are forced into the wood under substantial pressure. The protection afforded by creosote is, however, also limited in duration.

Of course wood may be displaced altogether for submerged structures by the use of iron or concrete, but the mechanical difficulties and the high expense of using either material are equivalent to a very high tribute paid for protection from our enemies; or, as we may prefer to put it "Millions for defense but not one cent for tribute!" Call it defense or tribute, as you please; in any event, until additional discoveries may be made, we protect our submarine structures from the depredations of marine borers only through very great expense in initial costs or in frequent replacements.

Shipworms and their allies remind one of the man who made his living suing the railroad. How did he live before the railroad was built? Some one also asked how mosquitoes found satisfaction and profit in life before man invaded their haunts. So the question occurs: Were there no cohorts of shipworms before civilization developed to the point where men "went down to sea in ships" or built structures out into the shore waters. It must be remembered that forests and rivers are nearly as old as the sea, and there were floating logs before there were ships or the hollowed logs that served for transportation of coastal tribes of men. Nor have marine borers been altogether dependent upon the chance log that drifted into their habitat. Along the shores of tropical countries there have long existed forests of mangroves whose aerial roots hang down into the salt or brackish waters, to serve as lodging places for oysters, barnacles and other living things of the sea. Not often can a shipworm find a suitable home in the green and growing tree, but one of its "associated powers," the tribe of pillbug borers, is not disturbed by the presence of flowing sap. No matter how green the stem or root, these "shock troops" assuredly cut their trails through the bark and into the wood, causing eventually the death of the affected piece. The way thus prepared for the main forces, the molluscan borers soon fill the dead wood with their burrows, until finally it is so weakened as to fall away and bear its burden of oysters to the mud.

So when man appeared with his floating and fixed structures, the triple alliance of shipworms, pillbugs, and feathered borers, were not found in a state of unpreparedness. All the methods of submarine attack had been developed, the armies were in training and the invisible warfare began at once. "Sunk without warning" must have been the sad report of one of the early sailors of the sea.

Did the wise neighbors jeer the unfortunate victim of a bold impulse to brave the sea, or did the tribe in sympathy and alarm assemble to propitiate their god? We do not know, but we can imagine that, sooner or later, the cause was sought by some inquiring mind and that in time it was discovered that, by keeping the family log in fresh water and sea water alternately or by regularly hauling it out in the sun, the trouble was obviated—the unseen enemy defeated.

Thus began this war against war, and, as marine structures increased in number, size and complexity, new tactics of defense were evolved. And yet, here we are in the 20th century still relatively defenseless, and only beginning to realize that, did we devote one half the thought and scientific skill to the age-old submarine war that we recently did to a man-made under sea attack, we might have an earlier hope to win a battle of the ages—the battle of the borers.